LAKE BLUFF FLOOD STORAGE SITE
FEASIBILITY STUDY
SKOKIE RIVER WATERSHED

Prepared For

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&

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EXECUTIVE SUMMARY

Christopher B. Burke Engineering, Ltd. (CBBEL) investigated the economic feasibility of a potential flood storage site for the Skokie River located in the Village of Lake Bluff, Lake County, Illinois. The focus of this study is an approximately 84-acre parcel located on the east side of the Skokie River, south of Illinois 176 (Rockland Road) between US 41 (Skokie Highway) and Green Bay Road.

As part of a previous study prepared for the East Skokie Drainage District (ESDD), CBBEL determined several drain tile replacement alternatives that reduced flood elevations in the Skokie River headwaters. A total of nine drain tile replacement alternatives were developed that provide various reductions in flood elevations.

The previously determined drain tile replacement alternatives for the Skokie River headwaters were combined with various reservoir sizes at the Lake Bluff site, which ranged from a 250 acre-foot gravity wetland flood storage facility to a 2,000 acre-foot deep, pump-evacuated reservoir. By combining the drain tile replacement alternatives with the Lake Bluff flood storage, a total of 43 scenarios were analyzed in this study.

A hydrologic and hydraulic analysis, based on the Flood Insurance Study (FIS) and enhanced with survey information, was developed to establish the baseline conditions flood elevations for Skokie River throughout Lake County. These enhanced models served as the existing conditions models and are the basis for comparison for the proposed alternatives analysis. A proposed conditions hydrologic and hydraulic analysis was prepared for each of the 43 drain tile replacement/Lake Bluff flood storage scenarios to determine the flood reductions of each alternative.

The Illinois Department of Natural Resources – Office of Water Resources (IDNR-OWR) surveyed the low entry elevations of approximately 1,600 structures throughout Lake County. This survey information, along with the existing conditions flood profiles determined by CBBEL, were input into a Damages 4.22 flood damages model to quantify the existing flood damages in Lake County. The 43 proposed conditions flood profiles were also input to the flood damages model to quantify the benefits associated with the flood reductions

Cost estimates were prepared for the Skokie River headwaters improvements and the Lake Bluff flood storage options. The cost estimates range from $3.1M to $156M. The flood reduction benefits of the proposed drainage improvements were compared to these costs to develop a benefit to cost ratio for each scenario. The benefit to cost ratios vary from 0.03 to 0.47. The minimum benefit to cost ratio is for the alternative with no drainage improvements in the headwaters and 2,000 ac-ft of flood storage at the Lake Bluff Flood Storage Site. The maximum benefit to cost ratio is for Alternative 1, which includes moderate upsizing of the drain tiles in the headwaters with no flood storage at the Lake Bluff Flood Storage Site.

INTRODUCTION

This report presents the results of a flood storage feasibility study conducted by Christopher B. Burke Engineering, Ltd. (CBBEL) in cooperation with the East Skokie Drainage District (ESDD), Lake County Stormwater Management Commission (SMC) and the Illinois Department of Natural Resources – Office of Water Resources (IDNR-OWR). The objective of this study was to determine the feasibility of flood storage at the approximately 84-acre parcel located on the east side of the Skokie River, south of Illinois 176 (Rockland Road) between US 41 (Skokie Highway) and Green Bay Road, in the Villages of Lake Bluff and City of Lake Forest), Lake County, Illinois. This parcel, known as the Lake Bluff Flood Storage Site, is shown on Exhibit 1. The parcel is co-owned by the State of Illinois and the Lake County Forest Preserve District (LCFPD). The Lake Bluff Flood Storage Site was originally purchased for the purpose of flood storage and has been previously studied with regards to its flood storage potential. In those studies, the site also included parcels owned by the Village of Lake Bluff as shown on Exhibit 2 and outlined in the 1988 Intergovernmental Agreement between the Village of Lake Bluff, LCFPD, the State of Illinois and ESDD. The current study focuses on utilizing only the parcel owned by the State of Illinois and the LCFPD for flood storage.

The current study investigates the flood reduction benefits from placement of additional flood storage at the Lake Bluff Flood Storage Site and conveyance improvement projects in the headwaters. A full range of flood storage options at the Lake Bluff Flood Storage Site were investigated. A total of five conceptual reservoir sizes were analyzed in this study, from a gravity drained wetland-bottom option with a volume of 250 acre-feet to pump-evacuated option with a volume of 2,000 acre-feet. The conceptual reservoir plans were designed to minimize impacts to the high-quality natural areas on the Lake Bluff Flood Storage Site.

To maximize the flood reduction in the watershed, conveyance improvements were investigated to convey the water from the flooding locations in the headwaters to the Lake Bluff Flood Storage Site. These conveyance improvements were studied in detail in the December 2008 study prepared for the East Skokie Drainage District (ESDD) by CBBEL. This study was used as the starting point for the hydrologic and hydraulic analysis in the current study and is summarized in this report. The current study expands on the previous one by pairing conveyance improvements in the headwaters with flood storage options at the Lake Bluff site. Hydrologic and hydraulic models were developed for 43 proposed conditions combinations and flood profiles for the 2-year through 100-year return interval design storm event were generated for each combination.

The Illinois Department of Natural Resources – Office of Water Resources (IDNR-OWR) developed a Damages 4.22 economic computer model to quantify the existing Skokie River flood damages. This model utilized the results of the hydraulic analysis and the surveyed low-entry elevations for over 1,600 structures adjacent to the Skokie River in Lake County. The existing conditions flood hydrologic and hydraulic model results were entered into the economic model to determine the baseline damages for the watershed. The flood profiles for each drain tile replacement/Lake Bluff storage scenario were also input to the Damages 4.22 model to quantify the flood reduction benefits associated with each proposed scenario. The flood reduction benefits were compared to the concept-level cost estimates to determine the benefit-cost ratio for each scenario.

EXISTING WATERSHED CONDITIONS

As documented in previous studies, overbank flooding from the Skokie River has caused significant damages within the watershed in the past. The municipalities of Gurnee, Waukegan, Park City, North Chicago, Lake Forest, Lake Bluff, and Highland Park are located adjacent to the Skokie River and have experienced varying degrees of overbank flooding from the river. The watershed is urbanized and nearly fully built-out, with much of the development having occurred prior to modern stormwater management practices such as stormwater detention and floodplain management.

A significant portion of the flood damages are located in the headwaters of the Skokie River. The municipalities of Gurnee, North Chicago, Waukegan and Park City experience significant flooding for even small storm events due to man-made obstructions and drain tile systems that form a series of dams in the headwaters. Under existing conditions, low flows in the headwaters of the Skokie River are conveyed by drain tiles. Higher flows are conveyed overland, but many of the overland flow paths and channel sections have been filled in. The raised overland flow paths impound a significant amount of water to a depth of up to ten feet for events as frequent as the 10-year return interval storm event. The drain tiles in the headwaters are undersized and in poor condition, and this area experiences frequent flooding, even during small storm events. Evidence of this can be clearly seen on the FIS profiles, which are included as Exhibit 6 and the City of Waukegan flood profiles for recent historical events contained in Appendix 5. A historical USGS topographic map showing the Skokie River in the headwaters prior to the obstructions is provided in Appendix 5.

Downstream of Illinois Route 137, the flow is conveyed south in an open channel towards the county boundary. Through the cities of Lake Forest and Highland Park, the Skokie River is a well-defined channel with approximately eight to ten feet of depth between the channel invert and the top of bank. There are nearly a dozen road crossings between Illinois Route 137 and the county boundary. The FIS profile indicates that these crossings do not have a significant impact on flood elevations, which are primarily controlled by the channel slope and riverine cross-section. The flood storage created by the impoundments in the headwaters reduces downstream flood flows through the Village of Lake Bluff and the City of Lake Forest, resulting in fewer flood damages for those communities. There is also significant open space within these communities located adjacent to the river that can store floodwaters without damage. The City of Highland Park, located further downstream near the Lake-Cook county boundary, does not benefit from the flood storage in the headwaters and also experiences overbank flood damages.

PROPOSED DRAINAGE IMPROVEMENTS

The scope of the study included conveyance and storage improvements in the headwaters and flood storage at the Lake Bluff Flood Storage Site. These drainage improvements are described below and shown on Exhibit 3.

Drain Tile Improvements in the Headwaters

The drain tile improvements in the headwaters are described in detail in the December 2008 CBBEL study, which focused on the industrial area north of Washington Street in the municipalities of Gurnee, Park City and Waukegan south to Rockland Road (Illinois Route 176) in Lake Forest. There are three sections of drain tile that were proposed to be replaced within the headwaters as part of that study:

- a 42-inch diameter tile upstream and downstream of Illinois Route 120 (Belvidere Road),
- dual 28-inch tiles upstream and downstream of Casmir Pulaski Drive and
- dual 24-inch tiles from upstream of Martin Luther King Drive (22nd Street) through the Navy Golf Course.

The December 2008 CBBEL study analyzed multiple tile replacement configurations that will be used in the current study. The results of the December 2008 study concluded that to achieve significant flood reductions in the headwaters, major drainage improvements would be required. These would include replacing the existing drain tiles with multiple large diameter pipes or open channel sections. The significant drainage improvements cannot be made unless flood storage is proposed to offset the increase in conveyance.

Flood Storage in the Headwaters

In July 2006, STS Consultants, Ltd. performed a flood control feasibility study for the Lake County Stormwater Management Commission (SMC). The STS study investigated approximately 30 flood storage alternatives from upstream of Washington Street to Buckley Road (Illinois Route 137).

- Skokie Headwaters Flood Storage Site A: Site located north of Washington Street with existing wetlands located on-site. By expanding the existing wetlands, it was estimated that between 11 and 38 acre-feet of flood storage could be provided.

- Skokie Headwaters Flood Storage Site B: Also known as the Zeman Parcel, site is located south of Washington Street, adjacent to the Farmington Estates Mobile Home Park. Potential flood storage ranges between 99 and 290 acre-feet provided by gravity and pumped options.

- North Chicago Flood Storage Site 1: - Also known as the Gillette Parcel, this site is located just south of Casimir Pulaski Drive (14th Street). Storage options range from a gravity, on-line reservoir that provides 60 acre-feet of storage to a pump-evacuated option that provides 220 acre-feet of storage.

- North Chicago Flood Storage Site 3: -This site is located south of Martin Luther King, Jr. Drive (22nd Street), east of the Skokie River. This site has the potential to create approximately 30 to 46 acre-feet of new flood storage.

These were incorporated into the December 2008 CBBEL study, which included combinations of larger pipe sizes with various headwaters flood storage areas from the STS study. The proposed flood storage configurations from the STS study are provided on the CD-ROM in Appendix 6.

Abbott Property Overflow Channel

The historic river channel through the Navy Golf Course has been elevated and creates a significant impoundment in the headwaters of the watershed. The existing overflow route at this location has been manipulated in the recent past to increase conveyance and protect the adjacent Abbot Laboratories structures south of 22nd Street. As part of the current study, the existing overflow route was surveyed and incorporated into the existing conditions analyses. Under proposed conditions, additional conveyance improvements are proposed to increase the capacity of the overflow channel at lower elevations. The proposed overflow channel would be a trapezoidal channel with a bottom width of 25 feet. It would be approximately 3,700 feet long and would require easements from Abbott, the Navy Golf Course, Commonwealth Edison and the North Shore Sanitary District. A concept plan of the proposed overflow channel is provided in Appendix 5. The proposed overflow channel improvements would reduce size and number of pipes required to replace the Navy Golf Course drain tiles while achieving the same flood reduction benefits.

Conveyance Improvements from Illinois Route 137 to Lake Bluff Storage Site

To significantly reduce flood depths in the headwaters, large pipes or open channel sections are required to replace the existing drain tiles. There is not adequate open space available in the headwaters to provide the floodwater storage that is required to offset the increased flowrates for those alternatives that include the large pipe sizes or open channel sections in the headwaters. The December 2008 CBBEL study contemplated providing storage for some of these improvements at the Lake Bluff Flood Storage Site. Under this scenario, conveyance improvements or flood easements would be required from Illinois Route 137 to the Lake Bluff Flood Storage Site to accommodate the increased flowrate from the drainage improvements in the headwaters. For the purpose of this study, it was assumed that conveyance improvements between Illinois Route 137 and the Lake Bluff Storage Site would be required and are summarized as follows:

- The existing culverts at Buckley Road, Alaska Avenue, Wyoming Avenue, and Alabama Avenue would need to be upsized for the majority of the drain tile alternatives.
- Channel widening would be required through the Lake Bluff Golf Course and just upstream of the Lake Bluff flood storage site (south of Rockland Road).
- Bridge modifications would be required at the EJ&E Railroad bridge and at the Rockland Road bridge.

The conveyance improvements were identified at a conceptual level and were incorporated into the hydraulic models. These improvements are included in the cost estimates, but no concept plans for these improvements were prepared.

Lake Bluff Flood Storage Site

The Lake Bluff Flood Storage Site was the primary focus of this study. The approximately 84-acre parcel is located on the east side of the Skokie River, south of Illinois 176 (Rockland Road) between US 41 (Skokie Highway) and Green Bay Road, in the Village of

Lake Bluff and City of Lake Forest in Lake County, Illinois, as shown on Exhibit 1. The parcel was purchased by the State of Illinois and the Lake County Forest Preserve District (LCFPD) for the purpose of flood storage. A 1998 Intergovernmental Agreement (IGA) between the State of Illinois, LCFPD, Village of Lake Bluff and the East Skokie Drainage District provides an arrangement for property ownership, development of the flood storage facility and maintenance. This IGA is contained in Appendix 5. The current study focuses on placement of flood storage on the parcel owned by the State of Illinois and the LCFPD. It is anticipated that the other parcels detailed in the IGA may or may not be used for placement of fill from the excavated flood storage facility. This will not affect the hydrologic and hydraulic analysis or flood damage analysis, but will have a significant impact on the conceptual cost estimate for the flood storage facility. A range of excavation costs were prepared assuming that the excavated material may or may not be hauled off site.

Currently, the Lake Bluff Flood Storage site is composed primarily of open space. A small pond exists on the project site, surrounded by areas of dense forest and grassland. Residential areas are located north and east of the project site.

Previous Studies of the Lake Bluff Storage Site

The potential for flood storage at this site in the Skokie River Watershed was first identified in the 1974 North Branch of the Chicago River Floodwater Management Plan (FMP). The 1974 FPM recommended construction of a 1,445 acre-ft flood storage facility at the Lake Bluff Flood Storage Site, referred to as Structure 4. This study led to several subsequent studies that are summarized below.

1983 Phase 1 General Design Memorandum

A Phase 1 General Design Memorandum study was prepared by the U.S. Army Corps of Engineers (COE) in 1983 to further develop the concept of flood storage at this location in the watershed. A benefit-to-cost analysis was developed for the watershed, and the recommended plan did not include the Lake Bluff Flood Storage Site (Structure 4).

1983 Environmental Impact Statement

An Environmental Impact Statement (EIS) was prepared by the COE in 1983 that included input from a variety of sources such as the U.S. Fish and Wildlife Service, Northeast Illinois Planning Commission (NIPC), Illinois Department of Conservation and other stakeholders. Similar to the 1983 GDM, the plan recommended by the EIS did not include the Lake Bluff Flood Storage Site (Structure 4).

1986 Archeological Survey

An Archeological Survey was prepared in 1986 by the Great Lakes Archeological Research Center. The findings indicated that there was no evidence historic or prehistoric archeological sites at this location.

1986 Breeding Bird Census

A Breeding Bird Census Report was prepared in 1986 by Lake County Avian Environmental Studies. The report indicated that the bird community at the site was dominated by abundant or common species. No endangered or threatened species were encountered on the site.

Geotechnical Information

A geotechnical assessment of the Lake Bluff food storage site was prepared for this site in 1987 by Testing Service Corporation. The major geotechnical findings from that report are summarized by the following:

- The majority of the soil beneath the project site is classified as fine grained silty clay
- There are two aquifers located beneath the site:
    - The upper aquifer is near the surface and is unconfined, forming a water table.
    - The lower aquifer is a water supply aquifer, located approximately between the elevations of 625 – 630 ft.
- Groundwater management such as a cut-off wall and subsurface drains will likely be required around the perimeter of the proposed reservoir to prevent groundwater infiltration into the basin.

Current Wetland Delineation

On May 13 and May 22, 2008 Christopher B. Burke Engineering, Ltd. completed field reconnaissance at the Lake Bluff Flood Storage Study Site in Lake Bluff, Lake County, Illinois. Six wetlands/waters of the U.S. areas were identified during the site visit and via aerial photography. The onsite wetlands/waters of the U.S. were flagged and field located using a hand-held, sub-meter accuracy GPS unit. Approximately 14.1 acres of wetlands/waters of the U.S. are located on the project parcel. The remainder of the study area consisted of woodland areas, a grassed recreational area, and a portion of the Skokie River. The wetland information is shown on Exhibit 4.

Lake Bluff Flood Storage Options

A wide range of conceptual reservoir sizes were analyzed in the current study, from a 250 acre-foot gravity wetland flood storage facility to a 2,000 acre-foot deep, pump-evacuated reservoir. The concept plans were based on the Lake County 2-foot aerial topographic mapping. The concept plans flood storage facilities were placed on the east side of the river to avoid the moderate quality woodland on the west side of the river and for ease of constructability. Included below is a brief summary of the five (5) conceptual flood storage configurations. It should be noted that each configuration has been developed only to a conceptual level that allows for analysis in the watershed models, estimate of natural resources impact and development of an engineers estimate of probable cost. If a flood storage facility is constructed, the ultimate configuration will be based on a considerable design effort that includes site specific topographic survey, updated natural resources studies and a detailed hydraulic analysis of the facility.

250 AC-FT Gravity Drained Flood Storage

As shown on Exhibit 7, 250 ac-ft of flood storage can be created by excavating the east overbank area down to an elevation of 659 ft, which is above the invert of the river and allows the flood storage area to drain by gravity to the Skokie River. The flood storage site could be planted with wetland vegetation and function as an overbank wetland and flood storage area. The footprint of the flood storage area minimizes the impacts on wetlands located on-site and avoids the managed woodland at the northern end of the parcel. This would be considered an online flood storage basin where the flood storage is accessed once the river banks are overtopped. Smaller-magnitude storm events, such as the 2-year event, will access the flood storage and a flood reduction benefit will be provided for those events. While this storage option provides flood storage benefits for both small and large

magnitude storm events, the resultant flood reductions from this option are not as substantial as the larger reservoir options. There are several drain tile replacement alternatives in the headwaters (Alternatives 2, 3, and 7) that require a volume greater than 250 ac-ft be provided at the Lake Bluff site.

500 AC-FT Pump-Evacuated Flood Storage

The details of this flood storage option are shown on Exhibit 8, and involve excavating the east overbank of the Skokie River down to an elevation of 643 ft. Because the bottom of the reservoir is below the invert of the river, this option requires a pump to evacuate the reservoir. Three 250-horsepower pumps, each with a capacity of 15,000 gallons per minute (gpm), are included in this conceptual design. Similar to the gravity storage option, the conceptual design of the 500 ac-ft reservoir minimizes the wetlands impacts located on-site while avoiding the managed woodland area at the northern end of the site. With the exception of one drain tile replacement alternative (Alternative #3), this reservoir option provides sufficient volume to offset the proposed upstream drainage improvements. The overflow weir for this option is configured to maximize the 100-year flood reductions while allowing the more frequent events to access the flood storage facility to offset conveyance improvements in the headwaters.

1000 AC-FT Pump-Evacuated Flood Storage

As shown on Exhibit 9, this reservoir option involves excavating the east overbank down to an elevation of 616 ft. The deep excavation and small footprint are proposed to limit impacts to the wetlands and woodlands located on-site. The overflow weir for this option is configured to maximize the 100-year flood reductions while allowing the smaller storm events, such as the 2- and 10-year storm events, to access the flood storage to offset the increases in flow due to the upstream conveyance improvements. This storage option provides sufficient storage to offset all conveyance improvement in the headwaters.

1500 AC-FT Pump-Evacuated Flood Storage

The conceptual design of this reservoir option is shown on Exhibit 10, and involves excavating the left overbank area down to an elevation of 626 ft. The footprint of the reservoir is designed to minimize the impacts to the wetland and managed woodland areas located in-site, but this volume could not be provided outside of the wetland/managed woodland area boundary. Avoiding the wetland area was given priority in the conceptual design. Therefore, the reservoir replaces the managed woodland area located at the northern end of the site. The overflow weir for this option is configured to maximize the 100-year flood reduction benefits while allowing the more frequent events to access the flood storage facility to offset conveyance improvements in the headwaters.

2000 AC-FT Pump-Evacuated Flood Storage

The conceptual design of this reservoir option is shown on Exhibit 11, and involves excavating the entire left overbank area down to an elevation of 628 ft. Similar to the other pumped reservoir options, the HWL is 666 ft. This volume could not be provided without impacting both the wetland and managed woodland areas of the site. The overflow weir for this option is configured to maximize the 100-year flood reduction benefits, but also provides flood reduction benefits for the smaller storm events, such as the 2-year storm event.

Non-Structural Measures

Under the scope of this study, non-structural measures such as buyouts, elevating, and flood-proofing were not investigated. These can be very effective measures to reduce flood damages.

HYDROLOGIC AND HYDRAULIC ANALYSES

The current Flood Insurance Study (FIS) hydrologic and steady-state hydraulic models were the baseline models utilized for the current study. Updated hydraulic information from the City of Highland Park was reviewed and incorporated into the analysis where applicable. Updates to the headwaters section of hydrologic and hydraulic models from the 2006 STS study were also included in the current analysis. Additionally, the models were enhanced with survey information provided by James Anderson Company. These enhanced models served as the existing conditions models and are the basis for comparison for the proposed alternatives analysis.

The hydrologic and hydraulic analysis was completed for the 2-, 10-, 50-, and 100-year return interval storm events using the 12-hour duration storm event, which is the critical duration storm event from the FIS and 2006 STS study. The 2006 STS study used the Illinois State Water Survey Bulletin 70 rainfall depths and area/quartile Huff Distributions for Cook County and the FIS model used an area-depth rainfall distribution and Bulletin 70 rainfall depths for Lake County. The current study was able to merge the two models together to incorporate the best available data while closely matching the current regulatory flood profiles. The existing conditions model includes the existing floodplain storage that is at the Lake Bluff Flood Storage Site today. A detailed description of the hydrologic and hydraulic analysis can be found in the December 2008 CBBEL report. A comparison between CBBEL's existing conditions analysis, the baseline conditions model from the STS report, and FIS profile is presented in Table 1.

TABLE 1
Comparison of CBBEL, STS and FIS 100-Year Flood Elevations/Flowrates

100-Year, 12 Hour Storm Event			
Location	CBBEL Headwater Elevation/Flowrate (ft/cfs)	STS Headwater Elevation/Flowrate (ft/cfs)*	FIS Headwater Elevation/Flowrate (ft/cfs)
Belvidere Road	697.04/227	697.17/209	696.65/320
Pulaski Road	696.49/267	696.30/262	696.45/323
MLK/Navy Golf Course	690.47/331	691.30/400	691.32/454
Buckley Road (IL 137)	683.39/438	684.13/484	684.13/484
Rockland Road (176)	668.91/805		668.82/747
Deerpath Avenue	661.15/1122		661.00/1044
Westleigh Road	658.03/1223		657.88/1142
Old Elm Road	651.28/1485		651.21/1410
Half Day Road (IL 22)	640.06/1667		639.94/1613
Park Avenue	639.73/1754		639.58/1689
Clavey Road	633.99/1825		633.88/1751

*STS study did not extend downstream of Buckley Road (IL137)

The existing conditions hydrologic and hydraulic analysis was revised to analyze the 43 proposed flood storage and headwaters conveyance improvement projects.

Baseline Alternative: No Headwaters Improvements and Lake Bluff Storage

Under this alternative, flood storage ranging from 250 ac-ft to 2,000 ac-ft was investigated at the Lake Bluff Flood Storage Site with no improvements in the headwaters of the watershed. The results of this analysis are presented in Table 2 and detailed summaries are provided on the CD-ROM in Appendix 6.

TABLE 2
Baseline Alternative 100-Year Flood Elevation Reductions

Location	100-Year Flood Elevation Reduction (ft)				
	Exist 250 Ac-Ft	Exist 500 Ac-Ft	Exist 1000 Ac-Ft	Exist 1500 Ac-Ft	Exist 2000 Ac-Ft
Washington Street	0.00	0.00	0.00	0.00	0.00
Belvidere Road (IL 120)	0.00	0.00	0.00	0.00	0.00
Casimir Pulaski Drive (14th Street)	0.00	0.00	0.00	0.00	0.00
Martin Luther King Jr Drive (22nd Street)	0.00	0.00	0.00	0.00	0.00
Buckley Road (IL 137)	0.00	0.00	0.00	0.00	0.00
Rockland Road (176)	0.17	0.11	0.16	0.18	0.19
Deerpath Avenue	0.31	0.33	0.54	0.71	0.84
Westleigh Road	0.32	0.23	0.38	0.51	0.61
Old Elm Road	0.02	0.08	0.02	0.2	0.33
Half Day Road (IL 22)	0.19	0.12	0.20	0.28	0.34
Park Avenue	0.23	0.15	0.25	0.34	0.41
Clavey Road	0.14	0.10	0.18	0.23	0.27

Alternative #1: No Additional Storage in Watershed and Lake Bluff Storage

Under this alternative, the proposed replacement drain tiles in the headwaters were increased in size until the flood elevations downstream of the Navy Golf Course were increased a maximum of 0.1 ft outside of the channel banks. This was assumed to be the maximum threshold allowable for a public flood control project. This alternative assumed that no future storage would be placed in the headwaters, and no future storage at the Lake Bluff Flood Storage Site is required. However, this alternative was run with the full range of storage configurations at the Lake Bluff Flood Storage Site. The proposed improvements consist of the following:

- Replacing the existing drain tile under Pulaski Road with a 36-inch diameter pipe.
- Replacing the existing drain tile under Martin Luther King Jr. Drive and the Navy Golf Course with a 42-inch diameter pipe (36-inch diameter storm sewer located in the Navy Golf Course was assumed to remain).
- Flood storage ranging from 250 ac-ft to 2,000 ac-ft at the Lake Bluff Flood Storage Site.

The results of this analysis are presented in Table 3 and detailed summaries are provided on the CD-ROM in Appendix 6.

TABLE 3
Alternative #1 100-Year Flood Elevation Reductions

Location	100-Year Flood Elevation Reduction (ft)				
	Alt 1 250 Ac-Ft	Alt 1 500 Ac-Ft	Alt 1 1000 Ac-Ft	Alt 1 1500 Ac-Ft	Alt 1 2000 Ac-Ft
Washington Street	0.00	0.00	0.00	0.00	0.00
Belvidere Road (IL 120)	0.00	0.00	0.00	0.00	0.00
Casimir Pulaski Drive (14th Street)	0.20	0.20	0.20	0.20	0.20
Martin Luther King Jr Drive (22nd Street)	0.12	0.12	0.12	0.12	0.12
Buckley Road (IL 137)	0.13	0.13	0.13	0.13	0.13
Rockland Road (176)	0.15	0.11	0.16	0.18	0.18
Deerpath Avenue	0.30	0.42	0.60	0.76	0.89
Westleigh Road	0.31	0.29	0.43	0.55	0.65
Old Elm Road	0.01	-0.10	0.09	0.25	0.38
Half Day Road (IL 22)	0.18	0.15	0.23	0.30	0.36
Park Avenue	0.22	0.19	0.28	0.36	0.43
Clavey Road	0.14	0.13	0.20	0.25	0.28

Alternative #2: Maximum Increase in Headwaters Storage and Lake Bluff Storage

This alternative assumed that the maximum amount of future flood storage in the headwaters from the 2006 STS report. The proposed drain tiles were increased in size until the floodplain in the headwaters were primarily contained within the channel banks. Flood storage was also proposed at the Lake Bluff Flood Storage Site. The proposed improvements for this alternative consist of the following:

- Adding two supplemental 60-inch diameter storm sewers under Belvidere Road (the existing tile system at this location is composed largely of RCP in good condition, so it is not proposed to be replaced).
- Replacing the drain tile under Pulaski Road with two 12-foot by 4-foot box culverts (equivalent to five 60-inch diameter circular pipes). This would be hydraulically similar to an open channel at this location.
- Replacing drain tile under Martin Luther King Jr. Drive with two 12-foot by 5-foot box culverts (equivalent to seven 60-inch diameter circular pipes; 36-inch diameter storm sewer located in the Navy Golf Course was assumed to remain).
- Adding 38 acre-feet of flood storage at Skokie Headwaters Site A (Option 4A from 2006 STS report).
- Adding 290 acre-feet of flood storage at Skokie Headwaters Site B (Option 4B from 2006 STS report).

- Adding 220 acre-feet of flood storage at North Chicago Site 1 (Option 1D from 2006 STS report).
- Adding 37 acre-feet of flood storage at North Chicago Site 3 (Option 3C from 2006 STS report).
- Easements, channel improvements, and/or culvert replacements between IL137 and the proposed Lake Bluff site.
- Flood storage ranging from 250 ac-ft to 2,000 ac-ft at the Lake Bluff Flood Storage Site.

These improvements will require a significant expenditure for storm sewers and flood storage. In certain locations, these improvements will not fit within the district's existing drainage easements and creating an open channel may be more cost-effective than the multiple box culverts required to produce the desired flood reductions. The results of this analysis are presented in Table 4 and detailed summaries are provided on the CD-ROM in Appendix 6.

TABLE 4
Alternative #2 100-Year Flood Elevation Reductions

Location	100-Year Flood Elevation Reduction (ft)				
	Alt 2 250 Ac-Ft	Alt 2 500 Ac-Ft	Alt 2 1000 Ac-Ft	Alt 2 1500 Ac-Ft	Alt 2 2000 Ac-Ft
Washington Street	0.74	0.74	0.74	0.74	0.74
Belvidere Road (IL 120)	4.32	4.32	4.32	4.32	4.32
Casimir Pulaski Drive (14th Street)	5.77	5.77	5.77	5.77	5.77
Martin Luther King Jr Drive (22nd Street)	4.18	4.18	4.18	4.18	4.18
Buckley Road (IL 137)	-0.03	-0.03	-0.03	-0.03	-0.03
Rockland Road (176)	-0.06	-0.13	-0.10	-0.14	-0.14
Deerpath Avenue	0.16	0.43	0.53	0.76	0.90
Westleigh Road	0.23	0.33	0.41	0.54	0.66
Old Elm Road	-0.05	-0.03	0.07	0.24	0.40
Half Day Road (IL 22)	0.15	0.18	0.23	0.30	0.37
Park Avenue	0.19	0.22	0.28	0.36	0.43
Clavey Road	0.10	0.14	0.20	0.25	0.29

Alternative #3: Lake Bluff Storage Only

This alternative assumes that no future storage will be placed in the watershed other than the Lake Bluff site and a small gravity on-line flood storage facility at Skokie Headwaters Site A. At the time of the report writing, the City of Waukegan received some grant money for the flood storage of Site A. The drain tiles were increased in size until the flood profiles in the headwaters were primarily contained within the channel banks. The increase in flood flows within the watershed will be stored at the future Lake Bluff site. The proposed improvements for this alternative include the following:

- Adding three supplemental 12-foot by 5-foot box culverts at Belvidere Road (equivalent to ten 60-inch diameter circular pipes).
- Replacing the existing drain tile under Pulaski Road with five 12-foot by 4-foot box culverts (equivalent to 13 60-inch diameter circular pipes).
- Replacing the existing drain tile under Martin Luther King Jr. Drive with five 12-foot by 6-foot box culverts (equivalent to 19 60-inch diameter circular pipes; 36-inch drain tile located in the Navy Golf Course was assumed to remain).
- Adding 27 acre-feet of flood storage at Skokie Headwaters Site A (Option 2A from 2006 STS report).
- Easements, channel improvements, and/or culvert replacements between IL137 and the proposed Lake Bluff site
- Flood storage ranging from 1,000 ac-ft to 2,000 ac-ft at the Lake Bluff Flood Storage Site.

These improvements will require a significant expenditure for storm sewers and flood storage. In certain locations, these improvements will not fit within the district's existing drainage easements and creating an open channel may be more cost-effective than the multiple box culverts required to produce the desired flood reductions. The results of this analysis are presented in Table 5 and detailed summaries are provided on the CD-ROM in Appendix 6.

TABLE 5
Alternative #3 100-Year Flood Elevation Reductions

Location	100-Year Flood Elevation Reduction (ft)		
	Alt 3 1000 Ac-Ft	Alt 3 1500 Ac-Ft	Alt 3 2000 Ac-Ft
Washington Street	0.54	0.54	0.54
Belvidere Road (IL 120)	3.73	3.73	3.73
Casimir Pulaski Drive (14th Street)	3.97	3.97	3.97
Martin Luther King Jr Drive (22nd Street)	4.33	4.33	4.33
Buckley Road (IL 137)	-0.07	-0.07	-0.07
Rockland Road (176)	-0.14	-0.12	-0.12
Deerpath Avenue	0.53	0.56	0.74
Westleigh Road	0.42	0.39	0.53
Old Elm Road	0.09	0.03	0.22
Half Day Road (IL 22)	0.23	0.21	0.29
Park Avenue	0.28	0.26	0.35
Clavey Road	0.19	0.19	0.24

Alternative #4: Headwaters Storage and no Lake Bluff Storage

This scenario assumed that the maximum amount of future storage from the STS report is placed at Skokie Headwaters Site A and North Chicago Site 1, half of the maximum storage is placed at Skokie Headwaters Site B and North Chicago Site 3, and there will be no storage available at the Lake Bluff site. The drain tiles were increased in size until the flood elevations downstream of the Navy Golf Course are increased a maximum of 0.1 ft outside of the channel banks (the maximum threshold allowed by SMC for a public flood control project). The proposed improvements for this alternative include the following:

- Adding a supplemental 24-inch diameter storm sewer at Belvidere Road.
- Replacing drain tile under Pulaski Road with a 48-inch diameter pipe.
- Replacing drain tile under Martin Luther King Jr. Drive a 48-inch diameter pipe (36-inch diameter drain tile located in the Navy Golf Course was assumed to remain).
- The addition of 27 acre-feet of flood storage at Skokie Headwaters Site A (Option 2A from 2006 STS report).
- The addition of 78 acre-feet of flood storage at Skokie Headwaters Site B (Half of Option 1B from 2006 STS report).
- The addition of 90 acre-feet of flood storage at North Chicago Site 1 (Option 1A from 2006 STS report).
- The addition of 23 acre-feet of flood storage at North Chicago Site 3 (Half of Option 3A from 2006 STS report).
- Flood storage ranging from 250 ac-ft to 2,000 ac-ft at the Lake Bluff Flood Storage Site.

The results of this analysis are presented in Table 6 and detailed summaries are provided on the CD-ROM in Appendix 6.

TABLE 6
Alternative #4 100-Year Flood Elevation Reductions

Location	100-Year Flood Elevation Reduction (ft)				
	Alt 4 250 Ac-Ft	Alt 4 500 Ac-Ft	Alt 4 1000 Ac-Ft	Alt 4 1500 Ac-Ft	Alt 4 2000 Ac-Ft
Washington Street	0.54	0.54	0.54	0.54	0.54
Belvidere Road (IL 120)	0.29	0.29	0.29	0.29	0.29
Casimir Pulaski Drive (14th Street)	1.08	1.08	1.08	1.08	1.08
Martin Luther King Jr Drive (22nd Street)	0.26	0.26	0.26	0.26	0.26
Buckley Road (IL 137)	0.13	0.13	0.13	0.13	0.13
Rockland Road (176)	0.15	0.11	0.16	0.18	0.18
Deerpath Avenue	0.30	0.42	0.60	0.76	0.89
Westleigh Road	0.31	0.29	0.43	0.55	0.65
Old Elm Road	0.01	-0.1	0.09	0.25	0.38
Half Day Road (IL 22)	0.18	0.15	0.23	0.30	0.36
Park Avenue	0.22	0.19	0.28	0.36	0.43
Clavey Road	0.14	0.13	0.20	0.25	0.28

Alternative #5: Headwaters Storage and Lake Bluff Storage

This scenario included various storage locations throughout the headwaters and at the Lake Bluff site. The drain tiles at Belvidere Road, Pulaski Drive, and Martin Luther King Jr. Drive were increased in size. The increase in flood flows within the watershed will be

offset by the flood storage located on the Lake Bluff site. The proposed improvements for this alternative consist of the following:

- Adding two supplemental 60-inch diameter storm sewers at Belvidere Road.
- Replacing drain tile under Pulaski Road with two 12-foot by 4-foot box culverts.
- Replacing drain tile under Martin Luther King Jr. Drive with four 66-inch diameter pipes (36-inch diameter drain tile located in the Navy Golf Course was assumed to remain).
- Adding 38 acre-feet of flood storage at Skokie Headwaters Site A (Option 4A from 2006 STS report).
- Adding 290 acre-feet of flood storage at Skokie Headwaters Site B (Option 4B from 2006 STS report).
- Adding 220 acre-feet of flood storage at North Chicago Site 1 (Option 1D from 2006 STS report).
- Easements, channel improvements, and/or culvert replacements between IL137 and the proposed Lake Bluff site.
- Flood storage ranging from 250 ac-ft to 2,000 ac-ft at the Lake Bluff Flood Storage Site.

The results of this analysis are presented in Table 7 and detailed summaries are provided on the CD-ROM in Appendix 6.

TABLE 7
Alternative #5 100-Year Flood Elevation Reductions

Location	100-Year Flood Elevation Reduction (ft)				
	Alt 5 250 Ac-Ft	Alt 5 500 Ac-Ft	Alt 5 1000 Ac-Ft	Alt 5 1500 Ac-Ft	Alt 5 2000 Ac-Ft
Washington Street	0.74	0.74	0.74	0.74	0.74
Belvidere Road (IL 120)	4.13	4.13	4.13	4.13	4.13
Casimir Pulaski Drive (14th Street)	5.95	5.95	5.95	5.95	5.95
Martin Luther King Jr Drive (22nd Street)	2.87	2.87	2.87	2.87	2.87
Buckley Road (IL 137)	-0.09	-0.09	-0.09	-0.09	-0.09
Rockland Road (176)	-0.06	-0.1	-0.14	-0.13	-0.13
Deerpath Avenue	0.16	0.62	0.64	0.75	0.89
Westleigh Road	0.23	0.56	0.49	0.54	0.65
Old Elm Road	-0.05	0.26	0.17	0.23	0.38
Half Day Road (IL 22)	0.15	0.31	0.26	0.29	0.36
Park Avenue	0.19	0.38	0.32	0.36	0.43
Clavey Road	0.10	0.25	0.22	0.24	0.28

Alternative #6: Headwaters Storage with 72-Inch Pipe through Navy Golf Course

This scenario assumed that the online wetland storage is available at Skokie Headwaters Site A and half of the maximum storage is placed at Skokie Headwaters Site B. The drain

tiles at Pulaski Road and Martin Luther King Jr. Drive were increased in size but the existing drain tile at Belvidere Road will remain. The increase in flood flows within the watershed will be offset by the flood storage located on the Lake Bluff site. The proposed improvements for this alternative include the following:

- Replacing drain tile under Pulaski Road with a 54-inch diameter pipe.
- Replacing drain tile under Martin Luther King Jr. Drive with a 72-inch diameter pipe (36-inch diameter drain tile located in the Navy Golf Course was assumed to remain).
- The addition of 27 acre-feet of flood storage at Skokie Headwaters Site A (Option 2A from 2006 STS report).
- The addition of 78 acre-feet of flood storage at Skokie Headwaters Site B (Half of Option 1B from 2006 STS report).
- Easements, channel improvements, and/or culvert replacements between IL137 and the proposed Lake Bluff site.
- Flood storage ranging from 250 ac-ft to 2,000 ac-ft at the Lake Bluff Flood Storage Site.

The results of this analysis are presented in Table 8 and detailed summaries are provided on the CD-ROM in Appendix 6.

TABLE 8
Alternative #6 100-Year Flood Elevation Reductions

Location	100-Year Flood Elevation Reduction (ft)				
	Alt 6 250 Ac-Ft	Alt 6 500 Ac-Ft	Alt 6 1000 Ac-Ft	Alt 6 1500 Ac-Ft	Alt 6 2000 Ac-Ft
Washington Street	0.54	0.54	0.54	0.54	0.54
Belvidere Road (IL 120)	0.26	0.26	0.26	0.26	0.26
Casimir Pulaski Drive (14th Street)	1.36	1.36	1.36	1.36	1.36
Martin Luther King Jr Drive (22nd Street)	0.53	0.53	0.53	0.53	0.53
Buckley Road (IL 137)	0.13	0.13	0.13	0.13	0.13
Rockland Road (176)	0.1	0.08	0.12	0.14	0.14
Deerpath Avenue	0.24	0.51	0.65	0.74	0.86
Westleigh Road	0.27	0.39	0.49	0.53	0.62
Old Elm Road	-0.02	0.05	0.17	0.22	0.35
Half Day Road (IL 22)	0.17	0.21	0.26	0.29	0.34
Park Avenue	0.20	0.26	0.32	0.35	0.41
Clavey Road	0.12	0.18	0.22	0.24	0.27

Alternative #6A: Alternative #6 with Abbott Property Overflow

This alternative assumes the same drainage improvements that are included under Alternative #6, but also includes an approximately 43-foot wide trapezoidal overflow channel through the Abbott Property (adjacent to the Navy Golf Course). As shown in Table 9, the

added overflow channel does not reduce the flood elevations at the upstream end of the watershed (Washington Street and Belvidere Road) but significantly reduces the flood profile between the Navy Golf Course and Pulaski Road. The results of this analysis are presented in Table 9 and detailed summaries are provided on the CD-ROM in Appendix 6.

TABLE 9
Alternative #6A 100-Year Flood Elevation Reductions

Location	100-Year Flood Elevation Reduction (ft)				
	Alt 6A 250 Ac-Ft	Alt 6A 500 Ac-Ft	Alt 6A 1000 Ac-Ft	Alt 6A 1500 Ac-Ft	Alt 6A 2000 Ac-Ft
Washington Street	0.54	0.54	0.54	0.54	0.54
Belvidere Road (IL 120)	0.28	0.28	0.28	0.28	0.28
Casimir Pulaski Drive (14th Street)	1.55	1.55	1.55	1.55	1.55
Martin Luther King Jr Drive (22nd Street)	2.82	2.82	2.82	2.82	2.82
Buckley Road (IL 137)	-0.01	-0.01	-0.01	-0.01	-0.01
Rockland Road (176)	0.01	-0.11	-0.10	-0.09	-0.12
Deerpath Avenue	0.23	0.42	0.60	0.70	0.84
Westleigh Road	0.26	0.34	0.46	0.5	0.61
Old Elm Road	-0.02	-0.01	0.13	0.19	0.33
Half Day Road (IL 22)	0.17	0.18	0.25	0.27	0.34
Park Avenue	0.20	0.22	0.30	0.33	0.40
Clavey Road	0.12	0.14	0.21	0.23	0.27

Alternative #7: Washington-Belvidere Channel Improvements

This alternative assumes the same drainage improvements that are included under Alternative #2, but also includes channel improvements in the headwaters between Washington Street and Belvidere Road. The purpose of this scenario was to determine the flood reduction benefits of excavating/widening the existing channel in this area. The results of this analysis are presented in Table 10 and detailed summaries are provided on the CD-ROM in Appendix 6.

TABLE 10
Alternative #7 100-Year Flood Elevation Reductions

Location	100-Year Flood Elevation Reduction (ft)				
	Alt 7 250 Ac-Ft	Alt 7 500 Ac-Ft	Alt 7 1000 Ac-Ft	Alt 7 1500 Ac-Ft	Alt 7 2000 Ac-Ft
Washington Street	0.74	0.74	0.74	0.74	0.74
Belvidere Road (IL 120)	4.32	4.32	4.32	4.32	4.32
Casimir Pulaski Drive (14th Street)	5.77	5.77	5.77	5.77	5.77
Martin Luther	4.18	4.18	4.18	4.18	4.18

King Jr Drive (22nd Street)					
Buckley Road (IL 137)	-0.03	-0.03	-0.03	-0.03	-0.03
Rockland Road (176)	-0.06	-0.13	-0.1	-0.14	-0.14
Deerpath Avenue	0.16	0.43	0.53	0.76	0.9
Westleigh Road	0.23	0.33	0.41	0.54	0.66
Old Elm Road	-0.05	-0.03	0.07	0.24	0.40
Half Day Road (IL 22)	0.15	0.18	0.23	0.30	0.37
Park Avenue	0.19	0.22	0.28	0.36	0.43
Clavey Road	0.10	0.14	0.20	0.25	0.29

Alternative #8: Additional Storage at SMC Flood Storage Site B

This alternative assumed the same drainage improvements that are included under Alternative #7, but instead of adding 290 acre-feet of flood storage at Skokie Headwaters Site B, the storage volume was increased to 330 acre-feet. The purpose of this alternative was to remove the adjacent mobile home park from the 100-year floodplain. The results of this analysis are presented in Table 11 and detailed summaries are provided on the CD-ROM in Appendix 6.

TABLE 11
Alternative #8 100-Year Flood Elevation Reductions

Location	100-Year Flood Elevation Reduction (ft)				
	Alt 8 250 Ac-Ft	Alt 8 500 Ac-Ft	Alt 8 1000 Ac-Ft	Alt 8 1500 Ac-Ft	Alt 8 2000 Ac-Ft
Washington Street	0.74	0.74	0.74	0.74	0.74
Belvidere Road (IL 120)	5.01	5.01	5.01	5.01	5.01
Casimir Pulaski Drive (14th Street)	6.43	6.43	6.43	6.43	6.43
Martin Luther King Jr Drive (22nd Street)	4.31	4.31	4.31	4.31	4.31
Buckley Road (IL 137)	-0.03	-0.03	-0.03	-0.03	-0.03
Rockland Road (176)	-0.06	-0.13	-0.10	-0.14	-0.14
Deerpath Avenue	0.16	0.43	0.53	0.76	0.90
Westleigh Road	0.23	0.33	0.41	0.54	0.66
Old Elm Road	-0.05	-0.03	0.07	0.24	0.40
Half Day Road (IL 22)	0.15	0.18	0.23	0.30	0.37
Park Avenue	0.19	0.22	0.28	0.36	0.43
Clavey Road	0.10	0.14	0.20	0.25	0.29

Alternative #9: Maximum Storage at SMC Flood Storage Site B

This alternative assumed the same drainage improvements as Alternative #7, but increased the volume of the Skokie Headwaters Site B to 376 acre-feet. The objective of this alternative was to minimize the significant conveyance improvements by providing more storage in the headwaters. The proposed improvements for this alternative include the following:

- Adding one supplemental 42-inch diameter storm sewer at Belvidere Road.
- Replacing drain tile under Pulaski Road with one 12-foot by 4-foot box culvert.
- Replacing drain tile under Martin Luther King Jr. Drive and through the Navy Golf Course with two 60-inch diameter pipes and a 43-foot wide trapezoidal overflow channel.
- Adding 27 acre-feet of flood storage at Skokie Headwaters Site A (Option 4A from 2006 STS report).
- Adding 700 acre-feet of flood storage at Skokie Headwaters Site B (Option 4B from 2006 STS report). This is the maximum storage required based on the hydrologic model and could likely be reduced upon further analysis.
- Adding 220 acre-feet of flood storage at North Chicago Site 1 (Option 1D from 2006 STS report).
- Flood storage ranging from 250 ac-ft to 2,000 ac-ft at the Lake Bluff Flood Storage Site.

The results of this analysis are presented in Table 12 and detailed summaries are provided on the CD-ROM in Appendix 6.

TABLE 12
Alternative #9 100-Year Flood Elevation Reductions

Location	100-Year Flood Elevation Reduction (ft)				
	Alt 9 250 Ac-Ft	Alt 9 500 Ac-Ft	Alt 9 1000 Ac-Ft	Alt 9 1500 Ac-Ft	Alt 9 2000 Ac-Ft
Washington Street	0.54	0.54	0.54	0.54	0.54
Belvidere Road (IL 120)	4.64	4.64	4.64	4.64	4.64
Casimir Pulaski Drive (14th Street)	5.57	5.57	5.57	5.57	5.57
Martin Luther King Jr Drive (22nd Street)	3.83	3.83	3.83	3.83	3.83
Buckley Road (IL 137)	0.01	0.01	0.01	0.01	0.01
Rockland Road (176)	-0.04	-0.04	-0.04	-0.04	-0.04
Deerpath Avenue	0.22	0.52	0.69	0.97	1.19
Westleigh Road	0.26	0.40	0.51	0.81	1.07
Old Elm Road	-0.03	0.06	0.20	0.60	0.92
Half Day Road (IL 22)	0.16	0.22	0.28	0.44	0.45
Park Avenue	0.20	0.26	0.34	0.52	0.55
Clavey Road	0.11	0.19	0.23	0.33	0.40

Headwaters Alternatives Without Lake Bluff Flood Storage

With the exception of Alternatives 1 and 4, the Skokie River headwaters alternatives require flood storage at the Lake Bluff site to offset increases in flowrates due to the conveyance improvements. Without flood storage at the Lake Bluff site, the flowrate increases result in flood elevation increases greater than 0.1 feet outside of the channel banks, which was assumed to be the maximum threshold allowable for a public flood control project. This maximum allowable threshold applies to all flood events up to and including the 100-year flood event and a public flood control project is not considered to be permittable without this criteria being satisfied.

To quantify the flood elevation increases associated with the increased flowrates, each drain tile replacement alternative was analyzed without flood storage at the Lake Bluff site. As shown in Table 13, the increases in 100-year flood elevations exceed the 0.1-foot threshold for all alternatives except Alternatives 1 and 4. The flood elevation increases extend from the Navy Golf Course (just north of Buckley Road) downstream to Deerpath Avenue. The 100-year flood elevation increases dissipate further downstream and range from 0.01 – 0.09 feet at the county boundary. It should be noted that this table only includes flood elevations for the 100-year flood profile. The maximum allowable threshold of 0.1 feet would have to be met for the 2-, 10-, and 50-year flood profiles as well.

TABLE 13

Headwaters Drainage Improvements without Lake Bluff Flood Storage[1]

Location	100-Year Flood Elevation Reduction[2] (ft)									
	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 6A	Alt 7	Alt 8	Alt 9
Washington Street	0.00	0.74	0.54	0.54	0.74	0.54	0.54	0.74	0.74	0.54
Belvidere Road (IL 120)	0.00	4.32	3.73	0.29	4.13	0.26	0.28	4.32	5.01	4.64
Casimir Pulaski Drive (14th Street)	0.20	5.77	3.97	1.08	5.95	1.36	1.55	5.77	6.43	5.57
Martin Luther King Jr Drive (22nd Street)	0.12	4.18	4.33	0.26	2.87	0.53	2.82	4.18	4.31	3.83
Buckley Road (IL 137)	0.13	-0.85	-1.44	0.13	-0.81	0.13	-0.89	-0.85	-0.85	-0.25
EJ & E Railroad	-0.03	-4.56	-5.93	-0.03	-4.50	-3.87	-3.92	-4.56	-4.56	-0.39
Rockland Road (IL 176)	-0.01	-0.22	-1.09	-0.01	-0.19	-0.07	-0.08	-0.22	-0.22	-0.11
Deerpath Avenue	-0.01	-0.11	-0.19	-0.01	-0.11	-0.06	-0.06	-0.11	-0.11	-0.07
Westleigh Road	-0.01	-0.08	-0.30	-0.01	-0.08	-0.04	-0.04	-0.08	-0.08	-0.05
Old Elm Road	0.00	-0.02	-0.03	0.00	-0.02	-0.01	-0.01	-0.02	-0.02	-0.02
Half Day Road (IL 22)	-0.01	-0.06	-0.08	-0.01	-0.06	-0.04	-0.04	-0.06	-0.06	-0.05
Park Avenue	0.00	-0.06	-0.08	0.00	-0.06	-0.04	-0.04	-0.06	-0.06	-0.05
Clavey Road	-0.01	-0.06	-0.09	-0.01	-0.06	-0.03	-0.04	-0.06	-0.06	-0.04

[1]Does not include conveyance improvements between Buckley Road (IL 137) and Rockland Road (IL 176).
[2] A reduction in flood elevation is listed as a positive number, an increase in flood elevation is listed as a negative number.

Summary of Hydrologic and Hydraulic Model Results

The alternatives analysis performed for this study was to assess the effectiveness of various flood storage configurations at the Lake Bluff Flood Storage Site and proposed drain tile replacement projects in the headwaters of the Skokie River. The 43 alternatives were designed to span a wide range of pipes sizes and potential flood storage options. The concept designs for the alternatives were based on the SMC permit requirements for public flood control projects. It is acknowledged that some of the pipe size configurations may not be realistic or cost effective.

The maximum increase in water surface profile from the proposed conveyance improvements in the headwaters maximum was 0.1 ft. Several of the alternatives will require easements, channel improvements, and/or culvert replacements between IL 137 and the Lake Bluff site, which were included in this analysis at a conceptual level. The reduction in floodplain elevations in the headwaters varies from a negligible decrease to a decrease of several feet. The reduction in floodplain elevations downstream of the Lake Bluff Flood Storage Site varies from a negligible decrease to 1.2 feet. The 100-year floodplain reduction benefits of each alternative are summarized in Appendix 1. Based on the results of this hydrologic and hydraulic analysis, the following conclusions can be made:

- Providing greater storage volumes at the Lake Bluff Flood Storage Site corresponds to larger flood elevation reductions downstream of the proposed flood storage facility.

- The flood elevation reductions and flowrate reductions from flood storage at the Lake Bluff Flood Storage site diminish towards the Lake-Cook county boundary. For a 2,000 ac-ft flood storage facility, the 100-year flood elevation decrease at the county boundary is 0.3 ft and the flowrate reduction is 10%. The Skokie Lagoons are also located immediate downstream of the county boundary, which would further dampen any reductions in flood flows through the short stretch in Cook County prior to joining the Middle Fork of the Chicago River. Based on this and meetings with the project team, it was determined that the current study would stop at the county boundary because it was not considered likely that large flood damage reductions would occur in Cook County.

- To achieve significant reduction in flood elevations throughout the Skokie River headwaters, major drainage improvements are required. These include large pipes and storage areas that may not fit within the district's current drainage easements.

- Significant floodplain reductions in the headwaters are likely not permittable without providing some flood storage at the Lake Bluff site.

- If flood storage sites are not currently available, the deteriorating tiles can still be replaced with larger pipes than exist currently. This will provide flood reductions for the more frequent storm events, but will provide minimal flood reduction for the 100-year flood profile. The new pipes can also be upsized and a restrictor placed in the pipe until future flood storage comes online.

SKOKIE RIVER FLOOD DAMAGE ANALYSIS

The current flood damage analysis focuses on overbank flooding from the Skokie River. In addition to this type of flooding, sanitary sewer backup, combined sewer overflow, localized flooding and seepage can also be experienced during a flood event. These flood problems are typically not directly related to the flood heights on the Skokie River and were therefore not considered in this analysis. This is consistent with the 1983 General Design Memorandum by the COE.

Direct damages (structural and contents) occur to public, residential, commercial, and industrial property. Direct damages were calculated as follows: IDNR-OWR and SMC surveyed the low-entry elevations for a total of 1,600 Lake County structures within the overbank areas of the Skokie River Watershed. These structures are shown on Exhibit 12. These structures were assigned a monetary value. Most of the values were based on 2007 tax assessment data obtained from the Lake County Tax Assessment Office. Contents values for residential units were assumed to be 50% of the current structure value per the Apartment and Condominium Personal Property Cost Guide by E.H. Boeckh published by Insurance Company of Illinois. Contents values for commercial structures were a ratio of the structure value based on the type of business. Property value information combined with flood damage versus depth of flooding tables from the Federal Insurance Administration (HAZMUS model curves) and from the Corps of Engineers provided flood damage-elevation information for each structure.

Local traffic disruption damages, damage to utilities, increased public service (police/public works) costs, evacuation and cleanup costs, and others are indirect damages. Indirect average annual damages, including local traffic damages were assumed to be 20% of the direct average annual damages for the Skokie watershed. The standard 15% assumption for indirect damages was increased to 20% to account for increased traffic damages due to the extensive amount of inundated roadways.

Traffic damages to major roadways in the floodplain (Washington Street and Martin Luther King Jr. Drive) were calculated separately based on length of time flooded, traffic counts, average daily wage and detour routes.

Damages to golf courses were also included in the analysis to be consistent with the 1983 General Design Memorandum by the COE. These damages were calculated using the data from the 1983 General Design Memorandum from the COE, which included a detailed analysis of direct and indirect golf course damages. The total golf course damages from the 1983 report were converted to present value and divided among the golf courses to establish the existing conditions flood damage at each golf course. The golf courses were assigned to a municipality, and the reduction in damages for each golf course was based on the reduction of direct structure damage for that municipality.

Intangible damages include loss of life, health hazard and psychological threat to residents. No estimates of intangible damages were made. Total average annual damages discussed in this report are the sum of direct damages, indirect damages, major roadway transportation damages and golf course damages.

Existing Conditions Flood Damage Assessment

IDNR-OWR Damages 4.22 flood damages model, developed by the USGS, was used for a deterministic economic flood analysis along the Skokie River. All of the average annual direct and indirect damages for each structure are then added together to produce the total damages for existing conditions flooding in the watershed. This was provided by IDNR-OWR. Of the approximately 1,600 surveyed structures, there are a total of 157 structures that are classified as damaged. In this analysis, the term "damaged" applies to any structure that has a low-entry elevation (or low elevation of damage curve) below the 2-, 10-, 50-, or 100-year flood elevation at that location. The breakdown of the damaged structures by community is shown in Table 14.

TABLE 14
Damaged Structures in Lake County by Community

Community	Number of Damaged Structures	Percentage of Total Damaged Structures
Highland Park	74	47.1%
Lake Forest	4	2.5%
Lake Bluff	1	0.6%
North Chicago	6	3.8%
Park City	65	41.4%
Waukegan	7	4.5%
TOTAL	**157**	**100%**

As shown in Table 14, the majority of the damaged structures are located in the cities of Highland Park and Park City. The community with the fewest damaged structures is the Village of Lake Bluff, which only has one structure that makes up 0.6% of the total number of damages structures.

Under existing conditions, structural flood damage begins during the 2-year frequency storm event to 4 mobile homes, two commercial buildings and two commercial garages. Houses on the Skokie River begin experiencing flood damages at the 10-year frequency storm. Table 15 shows existing condition flood damages along the Skokie River from overbank flooding. These damages provide a basis for estimating the benefits (reduction in flood damages) generated from various potential flood control alternatives.

Table 15
Baseline Structure Flood Damages in Lake County

FREQUENCY (YEARS)	NUMBER OF STRUCTURES	STRUCTURE DAMAGES	CONTENTS DAMAGES	TOTAL DAMAGES
100	157	$1,975,773	$862,604	$2,838,377
50	88	$970,337	$490,073	$1,460,410
10	18	$260,354	$130,114	$390,468
2	8	$79,117	$32,730	$111,847

The total structure damages were converted to average annual damages and added to the golf course damages and transportation damages. The summary of average annual damages is provided in Table 16.

TABLE 16
Average Annual Flood Damages in Lake County by Community

Community	Average Annual Structure and Indirect Flood Damages	Percentage of Total Average Annual Structure Flood Damages	Golf Course Damages	Transportation Damages	Total Damages
Highland Park	$46,928	15.5%	$124,465	N/A	$171,393
Lake Forest	$7,044	2.3%	$49,786	N/A	$56,830
Lake Bluff	$42,818	14.1%	$24,893	N/A	$67,711
North Chicago	$67,455	22.2%	$49,786	$35,797	$153,038
Park City	$131,158	43.3%	$0	N/A	$131,158
Waukegan	$7,401	2.4%	$0	$32,277	$39,678
TOTAL	**$302,805**	**100%**	**$248,930**	**$68,074**	**$619,809**

Existing conditions flooding causes $302,805 of total average annual flood damages to 157 structures based on structure surveys and property value determinations in the watershed. These damages include $252,338 in average annual structural damages and contents damages and $50,468 in average annual indirect flood damages (20% of the direct damages). Of the direct structure damages, 30.1% are commercial, 47.7% are residential and 22.1% are public. Golf course damages account for $248,930 in average annual damages and transportation damages associated with Washington Street and Martin Luther King Drive account for $68,074 in average annual damages.

Total average annual damages for the Skokie River Watershed in Lake County is $619,809. The capitalized damage over 50 years is $12.0 million. The supporting documentation for the existing conditions economic analysis is included in Appendices 3 and 4.

Proposed Conditions Flood Damage Assessment

The economic analysis described above was repeated for each of the 43 proposed conditions scenarios that would be permittable based on the results of the hydrologic and hydraulic analysis. An economic analysis was not completed for the headwaters improvement alternatives that resulted in unacceptable flood increases downstream of IL137. The Damages 4.22 economic model analysis was completed by IDNR-OWR and the golf course damages and transportation damages were completed by CBBEL. Flood damage reduction benefits were considered to be the difference between the existing flood damage and the proposed flood damage for each scenario. A spreadsheet showing the flood damage reduction benefits is included in Appendix 4. The results of the proposed conditions flood damage assessment is summarized below:

- Without improvements in the headwaters (i.e., with only storage provided at the Lake Bluff site), the annual flood damage reduction benefits range from $61,438 to $106,760 ($1.2 million to $2.1 million in capitalized benefits). These benefits are realized in the municipalities of Lake Bluff, Lake Forest and Highland Park.

- The maximum annual flood reduction benefit of $515,287 ($10.0 million capitalized benefit) is achieved for Alternative 9 with 2,000 ac-ft of flood storage at the Lake Bluff Flood Storage Site.

- The minimum annual flood reduction benefit of $61,438 ($1.2 million in capitalized benefits) is achieved with no improvement in the headwaters and a 500 ac-ft flood storage reservoir at the Lake Bluff Flood Storage Site.

- With the exception of Alternative #3, which requires at least 700 acre-feet of flood storage be available at the Lake Bluff site, each of the proposed drain tile replacement alternatives were combined with each of the five reservoir sizing options.

Engineer's Estimate of Probable Cost

CBBEL and James Anderson Company developed an Engineer's Estimate of Probable cost for the proposed improvements. The unit costs were derived from recent Illinois Department of Transportation (IDOT) contracts to ensure current pricing. The estimates for the Lake Bluff Flood Storage Site were prepared by CBBEL and are shown in Table 17. The estimates include excavation, pumping station, spillway structure, restoration and a 10% contingency. The estimates do not consider wetland mitigation that may be required. A range of estimates was prepared reflecting the difference between stockpiling the excavated material onsite (low end) and removing the material to an offsite location (high end). The range was prepared because it is not known whether or not the excavated material could be stockpiled on adjacent property.

TABLE 17
Lake Bluff Flood Storage Site Engineer's Estimate of Probable Cost

Storage (ac-ft)	Cost (Low End)	Cost (High End)
250	$6.4M	$14.5M
500	$10.3M	$23.2M
1,000	$15.7M	$37.8M
1,500	$25.5M	$62.8M
2,000	$33.2M	$84.1M

An engineer's estimate of probable cost was also prepared for the drainage improvements in the headwaters outlined in Alternatives 1-9. The cost estimates for the headwaters flood storage area were taken from the 2006 STS study. The conveyance improvements were prepared by the James Anderson Company and the costs of these improvements are shown in Table 18. The cost estimates do not include land acquisition or flood easements. Detailed cost estimates of the improvements are provided in Appendix 2.

TABLE 18
Headwaters Improvements Engineer's Estimate of Probable Cost

Alternative	Cost
1	$3.1M
2	$53.2M
3	$26.2M
4	$18.3M
5	$51.7M
6	$13.2M
6A	$13.6M
7	$53.2M
8	$56.5M
9	$85.4M

The engineer's estimate of probable cost for the Lake Bluff Flood Storage Site were combined with the appropriate estimate for the headwaters improvements to generate estimates for the 43 scenarios. The estimates range from $3.1 million to $156 million. Alternative 9 with 2,000 ac-ft of flood storage at the Lake Bluff Flood Storage site is the most expensive scenario and Alternative 1 with no flood storage at the Lake Bluff Site is the least expensive.

Summary of Economic Analysis

Using this information, a benefit to cost ratio was developed for each scenario. The benefit to cost ratios vary from 0.03 to 0.47. The minimum benefit to cost ratio is for the alternative with no drainage improvements in the headwaters and 2,000 ac-ft of flood storage at the Lake Bluff Flood Storage Site. The maximum benefit to cost ratio is for Alternative 1 with

no flood storage at the Lake Bluff site. Extension of the analysis downstream into Cook County may capture more economic benefits from the flood storage at the Lake Bluff Flood Storage Site. However, due to the distance between the site and the county boundary, the reductions in flood flows and flood elevations are not significant as the Skokie River enters Cook County. It is anticipated that any benefits in Cook County would be a small percentage of the Lake County benefits.

The estimated costs of the flood reduction improvements are significant. The economic analysis captures a portion of the baseline flood damages and economic benefits from proposed flood control projects. There are other damages that are not directly addressed by this analysis including health and safety, cost of increased municipal operations during flood events, economic losses due to encumbered lands, etc. These can complicate the selection of the preferred alternative. The selection process for a drainage improvement alternative should include development of an overall strategy based on potential funding, project partners and flood reduction benefits. A phased approach will likely be required to implement any of the proposed alternatives. Future roadway projects, land planning, site development and drainage improvement projects in the watershed should take into consideration the findings of this study.

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APPENDIX 1

Summary of Skokie River Headwaters Proposed Alternatives

APPENDIX 2

Proposed Flood Storage/Drainage Improvements Cost Estimates

APPENDIX 3

Average Annual Damages Spreadsheet

APPENDIX 4

Average Annual Benefits Spreadsheet

APPENDIX 5

Correspondence and Project Documents

APPENDIX 6

CD-ROM